JUPITER ICY MOONS ORBITER
(An element of Project Prometheus)

LESSONS LEARNED NEWSLETTER

Exploring the habitable water worlds of Jupiter — Callisto, Ganymede,and Europa

SPOTLIGHT: First Issue of the JIMO Lessons Learned Newsletter

The JIMO Lessons Learned newsletter provides a short synopsis of lessons learned that have potential benefit to the JIMO Project Team. Web links are provided to take the interested reader to the detailed article describing the situation and measures one should take to prevent or limit similar occurrences. The lessons are gathered from several sources including, but not limited to, the NASA Lessons Learned Information System (LLIS) that contains lessons learned from over forty years in the aeronautics and space business. The JIMO Lessons Learned Newsletter can also help you share your lessons learned. To submit a lesson learned contact Vyga Kulpa at 256-544-1383 or e-mail Vyga.Kulpa@nasa.gov.

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THIS MONTH:

ESD: An Enduring and Insidious Threat to Flight Hardware (12-02-02)

Source: NASA LLIS Database Entry: **1317**
Submitted by: David J. Oberhettinger /JPL (818-542-6960)

Abstract: A number of incidents, some of them documented in other lessons learned, are listed to support the thesis that ESD remains an insidious threat to the integrity of flight hardware despite extensive NASA and industry experience with controlling ESD and its effects. The lesson references a number of NASA Reliability Preferred Practices that should be implemented on flight projects.

Lesson(s) Learned: Designers of ESD-sensitive devices and handlers of ESD-sensitive equipment cannot assume that routine ESD engineering principles and practices will continue to be adequate to prevent damage to flight equipment.

Recommendation(s): Plan implementation of the ESD-related practices documented in NASA Technical Memorandum 4322A, NASA Reliability Preferred Practices for Design and Test, including:

- "Assessment and Control of Electrical Charges," LLIS #0654.
- "Design Checklists for Microcircuits," Guideline LLIS #0680.
- "Electrostatic Discharge Control in GSE," LLIS #0685.
- "Spacecraft Thermal Control Coatings Design and Application," Practice No. PD-ED-1239.
- "Electrostatic Discharge (ESD) Control In Flight Hardware," LLIS #0732.
- "Design Practice to Control Interference from Electrostatic Discharge (ESD)," LLIS #0773.
- "Electrostatic Discharge (ESD) Test Practices," LLIS #0777.
- "Surface Charging / Electrostatic Discharge Analysis," LLIS #0788.
- "Analysis of Radiated EMI From ESD Events Caused by Space Charging," LLIS #0797.
- "Thick Dielectric Charging / Internal Electrostatic Discharge (IESD)," LLIS #0800.

Labels to identify electrostatic discharge sensitive (ESDS) devices.
The following labels are commonly used on containers and packaging to alert anyone who handles the ESDS devices on the need to use static-safe procedures before handling the devices. The one on the left is preferred.

The following verbiage should be placed beside the label:

CAUTION
Contains parts and
assemblies susceptible to damage by
Electrostatic Discharge (ESD)

TDRS-H S-Band Multiple Access Antenna Performance Shortfall (4-25-02)

Source: NASA LLIS Database Entry: **1180**
Submitted by: Marco Toral /GSFC (301-286-9861)

Abstract: The TDRS-H was launched on June 30, 2000 incorporated a number of new communication technologies including the Single Access Springback Reflector Antenna, transmitters and receivers operating at Ka-band and the S-band microstrip patch antenna elements used in the Multiple Access (MA) phase arrays. During In-Orbit Test (IOT), performance deficiencies were observed in the MA forward (MAF) and return (MAR) channels. Performance testing of individual return array elements was initiated revealing widely divergent gain and axial ratios for the elements when compared to pre launch factory measurements. BSS initiated a comprehensive anomaly investigation incorporating: 1) On-orbit testing of TDRS-H; 2) Laboratory performance investigation of flight MA antenna elements; and 3) Factory satellite system level MA testing using the TDRS-I then undergoing integration and test. Ultimately, BSS determined that the most probable cause of the observed performance was due to the MA array sunshield (thermal blanket) coming into contact with the antenna array elements. Such contact creates a dielectric loading of the microstrip patch radiators and transmission lines altering the phase relationship of the radiators and shifting the resonant frequency of the elements. Altering the phase relationship causes the element gain pattern to "squint" or move off axis by some 8 degrees. The peak directivity, resistive loss and VSWR (Voltage Standing Wave Ratio) performance of the MA antenna elements degraded as a result of the close proximity of the sunshield. The sunshield is held in contact with the elements by electrostatic force created by deep charging of the dielectric materials used in the construction of the antenna elements. In response, a negative "image" charge appears in the sunshield (since it is conductive and grounded), and the electrostatic attractive force field is created.

Lesson(s) Learned:

- The use of microstrip patch elements was a new design to BSS, and as such, received substantial attention during the design, development and test phase. However, the interrelated physics of the sunshield contact and performance shortfall were never fully understood.
- Designers assumed that the designed spacing between the elements and the sunshield would be achieved. (The designed spacing of approximately 1/2 inch is more than sufficient to eliminate the effect.)
- Designers of the sunshield mechanical retention were unaware of the electrostatic attraction force and assumed that the sunshield would maintain clearance in the zero gravity space environment.

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TDRS-H S-Band Multiple Access Antenna Performance Shortfall (Continued from Page 3)

- While formed beam (gain and axial ratio) tests were performed on the assembled MA array without the sunshield in flight configuration, and continuity tests were performed on each element after installation of the sunshield, there was no test designed to compare individual element gain and axial ratio performance between pre and post installation of the sunshield.
- During the anomaly investigation, laboratory tests of elements with the sunshield "touching" the elements yielded no significant effect. This was a false conclusion based on a test configuration that pulled the sunshield away from the element due to gravity.

Recommendation(s):

1. The Systems Engineering activity should, as part of the Systems Requirements Review, conduct a thorough review of all derived requirements, including interfaces, to establish that all requirements are identified, documented, and have been included in the verification process.
2. During the proposal and initial design phases of the project, carefully and thoroughly evaluate the heritage and prior application of the technology. In this case, the sunshield had been used in prior applications, but not with microstrip patch antenna elements.
3. During the Integration and test phases of the project, test the entire system in the final flight configuration. In this case the concern was focused on the RF loss of the sunshield rather than the dielectric loading impact.
4. Examine in detail all analyses of the on-orbit environment impact on the system. Not all aspects of the environment are easily simulated or tested (e.g. solar input, high energy plasma, etc) and verification of performance rests with the completeness and thoroughness of the environmental analyses.
5. During anomaly investigations, check and recheck conclusions, analyses and tests. It is easy to go down the wrong path when results of tests yield answers that match pre-conceived ideas.
6. Design the system for on-orbit test. In this case there was an ability to examine the performance of individual elements. In many systems, this is not the case.
7. Assure adequate clearance of dielectric or conductive material from resonant structures such as the microstrip circuitry including radiating RF antenna elements and transmission lines.

Evidence of Recurrence Control Effectiveness:

1. The design was altered to include standoffs over each forward and return antenna element. The standoffs assure a minimum separation of the element and the sunshield to avoid the RF performance impact.
2. Specific tests of TDRS-I were incorporated to determine if an individual element were exhibiting performance similar to one with a sunshield in forcible contact.
3. The entire TDRS-I system is tested in the final flight configuration.

Guideline for Developing Reliable Instrumentation for Aerospace Systems (2-01-99)

Source: NASA LLIS Database Entry: **0761**
Submitted by: Wislon Harkins/GSFC (202 358-0584)

Abstract: This Lesson Learned is based on Reliability Guideline number GD-ED-2215 from NASA Technical Memorandum 4322A, NASA Reliability Preferred Practices for Design and Test. Very early consideration of instrumentation (Note: for purposes of this lesson, the term instrumentation refers only to sensor and signal conditioning subsystems and will not include the data management subsystem) requirements compatible with vehicle or payload system monitoring and control requirements will result in:

(1) Choice of sensor technology and sensor hardware/software that is cost-effectively matched to specific vehicle environment, design, performance, and configuration requirements;
(2) Up-front consideration of the effects of instrumentation system and sensor maintainability, calibration, and reliability during the operational phase over the specified lifetime;
(3) Optimum sensor location, avoidance of failures due to vibration, shock, thermal and stress effects, efficient cable design and routing; and
(4) Lower costs of instrumentation system integration due to well thought-out and preplanned designs that are less subject to change during the development process.

Lesson(s) Learned: Without applying a structured and disciplined approach to instrumentation system requirements and design throughout the system life cycle, there is increased risk of excessive costs and lower probability of meeting mission and science measurement needs.

Recommendation(s): The development of in-flight instrumentation, vehicle health management systems, and sensor systems for control and monitoring should be thoroughly integrated into the requirements generation, preliminary design, and early planning for payloads and space flight systems. Multi-disciplinary Product Development Teams (PDTs) must include instrumentation considerations at the very front end of the development process. This will allow maximum advantage to be gained from current and emerging technologies to provide both real time and postflight diagnostics that will reliably and consistently reflect the system's condition. The result will be improved vehicle and payload system reliability through accurate and well-planned access to performance information. Emphasis must be placed on early definition of instrumentation and measurement requirements to reduce the time and cost to develop reliable instrumentation systems and ensure mission success.

Additional References:

1. NPD 7120.4, "Program/Project Management."
2. NPR 7120.5, "NASA Program and Project Management Processes and Requirements."
3. MSFC-HDBK-1912A, "System Engineering Handbook," December 6, 1994.
4. MSFC-STD-1924, "Standard for Instrumentation Program and Command Lists (IP&CL)," June 21, 1993.

Comet Nucleus Tour (CONTOUR) Mishap Investigation (12-05-03)

Source: NASA LLIS Database Entry: **1385**
Submitted by: Lisa Bonine/MSFC (256 544-2544)

Abstract: The Comet Nucleus Tour, CONTOUR, was designed and built by Johns Hopkins University and launched on July 3, 2002, was intended to encounter at least two comets to perform a variety of analyses on comet material. However, sometime after the solid rocket motor (SRM) intended to move the satellite out of eccentric earth orbit was fired, the satellite was lost. Mission design did not allow for observation or telemetry coverage during SRM burn, so the mishap investigation board was unable to determine with certainty the cause of the failure. However, a major finding of the investigation was that telemetry or visual coverage of the satellite during SRM burn was, in fact, possible and may help prevent similar mishaps in the future.

Description of Driving Event: Sometime after the solid rocket motor (SRM) intended to move the satellite out of eccentric earth orbit was fired, the satellite was lost. Mission design did not allow for observation or telemetry coverage during SRM burn, so the mishap investigation board was unable to determine with certainty the cause of the failure. However, a number of possible root causes were documented, along with recommendations for corrective actions. The probable proximate cause identified was overheating of the spacecraft by SRM exhaust plume. The following alternate proximate causes were identified:

- Catastrophic failure of SRM
- Collision of spacecraft with debris or meteoroids
- Loss of dynamic control of spacecraft

Lesson(s) Learned:

1. A major lesson learned was that all spacecraft should retain telemetry or visual contact during critical phases of the mission.

2. The team felt the mishap may have been driven by certain practices that the team described as more typical of small projects managed by contractor Principal Investigators. These practices include:

(a) Reliance of CONTOUR project on analysis by similarity. Although flight history of a selected component is one aspect of acceptance by similarity, it is important to consider whether the application is consistent and within the bounds of previous qualification.

(b) Inadequate systems engineering process and specification of requirements
The board cited the fact that few requirements were imposed by NASA regarding the way contractors document or performed work on CONTOUR, creating opportunities for contractors to adopt nonstandard engineering practices.

Comet Nucleus Tour (CONTOUR) Mishap Investigation (Continued from Page 6)

3. Inadequate review functions. The board felt that inadequate oversight was especially dangerous in combination with nonstandard engineering practices.

4. Other observations noted by the team were the lack of telemetry/observation of spacecraft during a critical mission event, a tendency to rely on subcontractors without appropriate insight/oversight, the use of analytic models that were not specific to CONTOUR, a limited understanding of SRM plume heating environments in space, the lack of an orbital debris conjunction plan, and a limited understanding of SRM operating conditions. These are covered in detail in the "CONTOUR Mishap Investigation Board Report."

Recommendation(s):

1. Always maintain telemetry or visual contact with spacecraft during critical phases of the mission.

2. Projects should conduct inheritance reviews (i.e. analyses by similarity) early in the project life cycle and should assure that the analysis properly evaluates the inherited item's capabilities and prior use against all mission critical requirements.

3. Projects should establish clear and appropriate requirements for performing and documenting engineering work.

4. Projects should establish mechanisms for increased NASA oversight for projects led by principal investigators.

SUGGESTIONS SOUGHT

- Your suggestions are valued and will help make this a better communications tool. Submit your ideas to Vyga Kulpa at Vyga.Kulpa@nasa.gov.

SOURCES

1. ESD: An Enduring and Insidious Threat to Flight Hardware - NASA LLIS: 1317
2. TDRS-H S-Band Multiple Access Antenna Performance Shortfall - NASA LLIS: 1180
3. Guideline for Developing Reliable Instrumentation for Aerospace Systems - NASA LLIS: 0761
4. Comet Nucleus Tour (CONTOUR) Mishap Investigation - NASA LLIS: 1385

LESSON LEARNED DATABASES:

- **NASA Lessons Learned Information System (LLIS)** http://llis.nasa.gov/
- **JSC Lessons Learned Database** http://iss-www.jsc.nasa.gov/ss/issapt/lldb/
- **Flights Programs and Projects Directorate (FPPD) Lessons Learned Database (FPPDLL)** http://eo1.gsfc.nasa.gov/miscPages/fppd-ll-database.html
- **EOS, the Earth Observing System** http://eos.gsfc.nasa.gov/eos-ll/index.html
- **NASA Technology Portal** http://nasatechnology.nasa.gov/?ntpo=1&CFID=90684&CFTOKEN=75170853